operate on seven different data types. In many cases, the use of this MULTIMODULE board results in two orders of magnitude performance enhancement over a software solution. This board is the subject of a subsequent section of this application note.

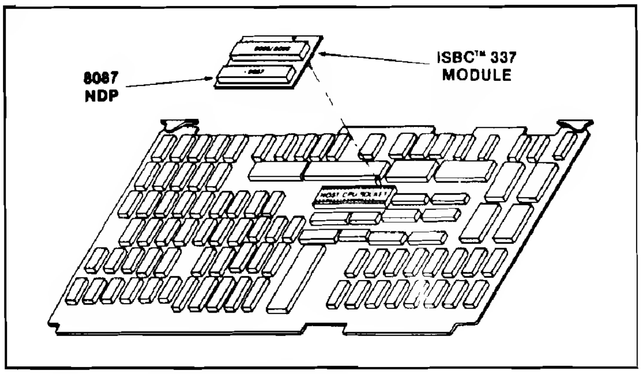

Figure 4. iSBC™ 337 MULTIMODULE™ Numeric Data Processor

APPLICATION EXAMPLE

The features of the iSBC 88/40 Measurement and Control Computer can best be shown through an example. This application note describes the classical control system application of an agitated heating tank. Figure 5 shows the prominent features of this process control applications. The process consists of a storage vessel, a temperature sensor which measures the temperature of the fluid leaving the vessel, and a steam coil whose steam flow is regulated by a proportional valve. A motor drives an agitator to insure the temperature of the tank remains homogeneous.

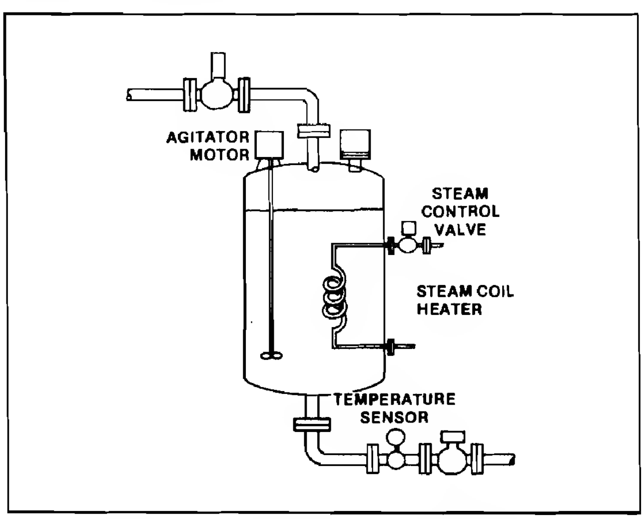

Figure 5. An Agitated Heating Tank

The passive portion of the application involves measuring the actual temperature of the fluid as it leaves the tank (and thus the temperature of all the fluid in the tank). If a control system is to be constructed which will control the temperature, an algorithm must be implemented which will provide control of the steam valve based upon the actual and the desired temperatures. This is the active portion of the application.

The control algorithm selected to control the tank temperature must be capable of compensating for disturbances created by a variety of conditions. For example, the temperature can be affected by changes in steam temperature, input temperature of the fluid, output flow rate, ambient temperature, and the flow rate of steam through the steam coil. Our control system will have control of only one of the variables and will only monitor the output temperature. To gain a degree of stability under these conditions, a feedback control algorithm is required. Alternatively, a system could be implemented using a feed-forward control algorithm. Unfortunately, the latter technique would require extensive instrumentation of all possible variables which could cause a disturbance. A feedback control system can take corrective action regardless of the source of a disturbance. Its chief drawback is that no corrective action is taken until an error is actually detected and, if not "tuned" correctly, some oscillations can occur.

Classical Controller Approaches

Before proceeding with a discussion of how a control system can be implemented using single board computers, a short discussion of classical control system theory is in order. This material will provide a background into the control algorithms which will be used as a basis for the digital control solution which will be developed.

The classical controller for feedback systems uses the "three mode" or PID (Proportional, Integral, Derivative) algorithm. In this system, the control output signal is a function of the error (the difference between the setpoint and the measured system variable). A specific application will use some combination of one, two, or all three terms making up the control statement.

Before continuing with the implementation of the control algorithm on the iSBC 88/40 Measurement and Control Computer, the various terms of the equation will be reviewed.

For Proportional control, the controller output is given by the equation:

$$m(t) = b + k_0 e(t) \qquad \textit{(eq. 1)}$$

where $m(t)$ is the output signal, b is an adjustable bias value, k_0 is a gain constant, and $e(t)$ is the measured error signal. Proportional control systems are normally

not used by themselves since corrections can not be made until an appreciable error has been detected. In addition, they tend to introduce oscillations into the system if the gain is set too large. Another disadvantage of proportional only systems is their inability to maintain a control element at some point (other than at its zero point using the bias term) in the absence of an error signal.

The second term in the PID solution is the Integral. The result of this term is to eliminate steady-state error or offset. The elimination of the offset is an important control objective; thus, the integral control term is widely used in conjunction with the proportional control element. The equation for the integral term is:

$$m(t) = (1/k_1)\, e(t)dt \qquad (eq. 2)$$

where k_I is the integral or reset time.

The Derivative term in the algorithm is used to provide an output which is a function of the rate of change in the error signal. It anticipates the future behavior of the system and improves the dynamic response to the controlled variable by decreasing the process response time. The format for the derivative term is:

$$m(t) = k_2(de/dt) \qquad (eq. 3)$$

where k_2 is a constant representing the derivative time expressed in seconds or minutes. Because the output of the term is zero for a constant error, derivative control is never used alone in a control system. Instead, it is always used in conjunction with proportional and integral control. The derivative term is seldom used in flow controllers because derivative control tends to amplify "noise" which is picked up in the flow measurement, leading to an unstable control system. In addition, systems which have very large time delays do not benefit from the use of this term.

Implementation Using Digital Techniques

With an exposure to the fundamental concepts of control theory complete, the development of a solution using the iSBC 88/40 Measurement and Control Computer can proceed. A modular "top-down" approach will be used in this application note. The general requirements will be defined and "black boxes" will be developed to meet these requirements. Finally, the individual pieces will be combined to form a complete solution to the agitated tank control problem.

An effective control algorithm must deal not only with the mathematical solution of the control equation, but must also provide tests on limits and error conditions. As this application note will show, the iSBC 88/40 Measurement and Control Computer is easily able to support these additional requirements.

Additional supporting functions are also needed to effectively implement a complete control system solution. For example, provisions must be made to support input and update of the controller setpoints. Allowances must be made to modify control algorithm constants in order to "fine tune" the system after start-up. Raw analog data must be filtered to eliminate spurious sensor measurements and then must be converted into engineering units. In earlier system implementations not based on digital computers, these functions were performed using a "black box" approach. Here, each function is considered separately and the final solution is composed of combinations of building blocks.

Digital technology offers a simple analogy to this approach. Because application design is performed with software, a "black box" design is available for use with microcomputers. The black box corresponds to a software "task" and the system is integrated into a functional unit using a real time operating system. The iRMX 88 Real Time Executive provides all the tools needed by the software designer to implement his required functions for the application. This application note will show how the iRMX 88 executive can be used to simplify the design and to provide significant features in a process design example.

Figure 6 shows a block diagram of the operations needed to implement the control of one loop for the agitated heating tank. An attribute of using digital microcomputers is that additional loops can be run using the same hardware and software until the I/O or processing capabilities have been exceeded.

Each element of the block diagram represents one function which must be performed by the system. A task will be written to perform the functions assigned to each block. When the tasks are configured together with the iRMX 88 executive, a complete control solution will result. Some key features of the iSBC 88/40 Measurement and Control Computer will now be examined and a typical implementation will be described.

ANALOG SUPPORT FUNCTIONS

The information presented in Figure 6 indicates that many functions involve the manipulation of analog data and its conversion into a digital form usable by the processor. This involves the use of both hardware and software. This section of the application note demonstrates how the iSBC 88/40 board features can be applied to the solution of the analog portions of the system implementation. Both software programming concepts and hardware support products are examined.